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CHARACTERISTICS OF HFC REFRIGERANTS

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ABSTRACT

Production restriction of CFC's which are used for refrigerators and air conditioners has been implemented through the international mutual agreement approved by the Montreal Protocol. Due to the less impact on the ozone layer depletion, alternative refrigerants for CFC's are R-123, R-22 and R-134a. However, HCFC refrigerants R-123 and R-22 do not completely prevent the ozone layer depletion. This paper presents the investigation results of HFC refrigerants R-125, R-143a, R-152a and R-32 which prevent the ozone layer depletion and are candidates for alternatives of CFC's and HCFC's.

The test results of thermal stability of these refrigerants are similar to those of R-12 and R-22. The test results show that each refrigerant has different material compatibility. The test results of lubricant solubility show that synthetic oils are soluble in these refrigerants, but the mineral oils currently in use for CFC's and HCFC's are not. The refrigeration performance based on the calculated thermodynamic properties corresponds with that of the experimental results.

INTRODUCTION

Recently, these HFC refrigerants are drawing attention as candidates for alternatives without the ozone layer depletion. However, the data are insufficient for officially adopting them as alternatives.

This paper presents the investigation results of thermal stability, material compatibility, lubricant solubility, thermodynamic properties and refrigeration effect of these refrigerants.

EXPERIMENTAL METHODS AND RESULTS

Table 1 shows the thermophysical properties of these new refrigerants R-125, R-143a, R-152a and R-32 in comparison with conventional refrigerants R-134a, R-12 and R-22 [1-5].

Lubricant solubility

We conducted the test with 4 kinds of oil by varying the mixture ratio of oil and refrigerant from 20 to 80wt.% and the temperature of the mixture from -70 to 90 ℃. The oils used for the test are polyalkylene glycol (PAG), ester and perfluoro ether (PFE) which were exclusively developed by oil makers for R-134a and the mineral oil currently used for R-12 and R-22. Table 2 shows the physical properties of oils.

The results of oil solubility test show that the mineral oils currently in use are not soluble in these refrigerants within the limit of these experimental conditions. Figures 1~3 show the results of other lubricants. Only PFE is soluble in R-143a. PAG and ester are soluble in R-32 and R-152a. All of the tested synthetic oils are soluble in R-125 and R-134a.

Thermal stability

Table 3 shows the test conditions. The oils used for this test are soluble in these refrigerants.

Figure 4 shows the test results of thermal stability. According to the analysis of the refrigerant decomposition using an ion chromatography under the 30-day heating test, the experimental results show that each tested refrigerant has thermal stability similar to that of R-12 and R-22. However, each refrigerant has different catalysis effect depending on the material.

Material compatibility

Material compatibility is an important factor for evaluating the reliability of refrigerating systems. Therefore, we investigated the material compatibility of polymeric materials such as plastics and elastomers which are commonly used for air-conditioners and refrigerators. The evaluation of material compatibility is based on the amount of the refrigerant absorbed by the material during the 2 week test of the material being immersed in the 50℃ saturated liquid refrigerant and the amount of the material absorbed by the refrigerant after this test and until the refrigerant evaporates out under the atmospheric pressure. Table 3 shows the tested material and the test conditions.

Figures 5~11 shows the test results. Each refrigerant has different material compatibility. Epoxy resin has relatively strong solubility in these refrigerants. Therefore, epoxy resin is not desirable for the use with those refrigerants.

Performance

The refrigeration performance based on the thermodynamic properties which are the calculated results using Mark O. McLinden's equation of critical parameters, vapor pressure and the ideal gas specific heat capacity.

Figure 11 shows the total system for testing refrigeration performance. A rotary type compressor and double-tube type heat exchangers are used for the test. Lubricants used for the test are PFE for R-143a and PAG for the other refrigerants.

Table 4 shows theoretical and experimental results of refrigeration performance under the same operating conditions. It shows the capacity and COP ratio of R-134a against the other refrigerants and the discharge temperature difference between R-134a and the other refrigerants. The refrigerants of lower boiling point such as R-32 gives higher capacity than those of higher boiling point such as R-152a. Figure 12 shows the calculated refrigeration capacity of these refrigerants under various evaporating and condensing temperatures. Due to high suction gas density, refrigeration capacity increases as evaporating temperature rises.

Table 4 shows that the calculated COP of R-152a is the highest in comparison with other refrigerants and that of R-125 is the lowest. The experimental COPs of R-125, R-143a and R-32 correspond with the calculated COP, but those of R-152a and R-134a do not correspond. The compressor used for this test is for R-22. Therefore, the experimental COP of R-125 which has similar property of R-22 correspond to the calculated COP. However, the property of R-152a is not similar to R-22. Therefore, the experimental COPs of R-152a and R-134a do not correspond to the calculated COP. If a compressor is designed specifically for these refrigerants, the calculated COP is likely to correspond with the experimental one. Figure 13 shows calculation data of COP under various evaporating and condensing temperatures. Under these operating conditions, as evaporating temperature rises, the COP of R-125 decreases and the COP of R-152a increases.

The discharge temperature of R-32 is the highest of all and those of R-152a, R-143a R-134a and R-125 follow. Therefore, R-32 is not desirable for practical application from the point view of high discharge pressure and temperature.

CONCLUSION

The preliminary investigation results show that HFC refrigerants such as R-125, R-143a, R-152a and R-32 are prospective alternatives for CFC's and HCFC's without ozone layer depletion.

Though the mineral oils which are currently in use for CFC's and HCFC's cannot be used as lubricant oil for these refrigerants, the tested synthetic oils (such as PAG, PFE and ester oils) are soluble. The thermal stability is similar to those of R-12 and R-22. These refrigerants have good material compatibility with the tested polymeric materials except for epoxy resin. R-152a has the highest COP, but the refrigeration capacity per unit displacement is low. R-32 gives the highest refrigeration capacity per unit displacement, but the discharge pressure and temperature are higher than those of other refrigerants.

Therefore, this investigation results at this stage do not conclude which HFC refrigerant is the most suitable as an alternative refrigerant. The future investigation includes the safety test to confirm the toxicity and flammability, the test of R-32 mixed with other refrigerants to confirm the possibility of this refrigerant as an alternative, the test of these refrigerants for obtaining more details of properties for finalization and the practical test to confirm the material compatibility and the lubricant issues over a long period.

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Table.1 Thermophysical properties for HFC refrigerants

Refrigerant	Molecular formula	Molecular weight	Boiling point ℃	Critical temperature ℃	Critical pressure kPa	ODP	GWP
R152a	CH_3CHF_2	66.05	-24.2	113.3	4520	0	0.03
R143a	CH_3CF_3	84.04	-47.7	73.1	3811	0	0.74
R125	CHF_2CF_3	120.02	-48.6	66.3	3631	0	0.58
R32	CH_2F_2	52.02	-51.8	78.4	5830	0	0.13
R134a	CH_2FCF_3	102.03	-26.2	101.15	4065	0	0.26
R12	CCl_2F_2	120.91	-29.8	111.80	4125	1.0	3.0
R22	$CHClF_2$	86.47	-40.8	96.15	4988	0.05	0.34

Table.2 Physical properties of oils

	Mineral oil (Naphthene series)	PAG	PFE	Ester oil
Viscosity [cSt] 40℃	55.5	30.8	65	29.3
Viscosity [cSt] 100℃	5.9	6.3	15	5.0
Pour Point [℃]	−40	−50	−75	<−50
Density [g/cm^3] 15℃	0.922	1.019	1.889	0.979

PAG : Polyalkylene glycol
PFE : Perfluoro ether

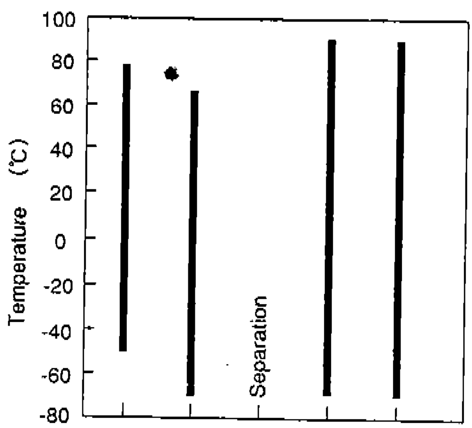

Fig.1 Lubricant solubility (PAG)

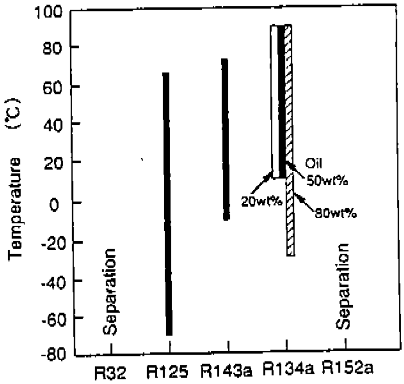

Fig.2 Lubricant solubility (P F E)

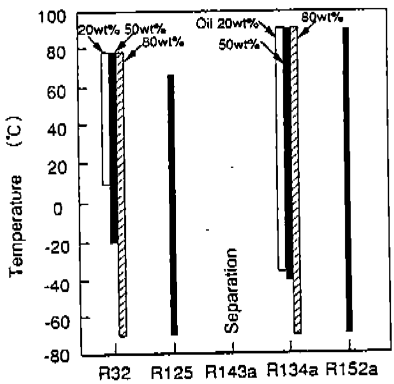

Fig.3 Lubricant solubility (Ester oil)

Table.3 Condition of thermal stability test

Refrigerant (91wt%)	R32	R125	R152a	R143a	R12	R22
Lubrication oil (9wt%)	P A G , Ester oil			P F E	Mineral oil (Naphthene series)	
Metal	Fe , Al , Cu					
Water	0.0 , 0.2%					
Temperature	120℃					
Heating period	30 days					

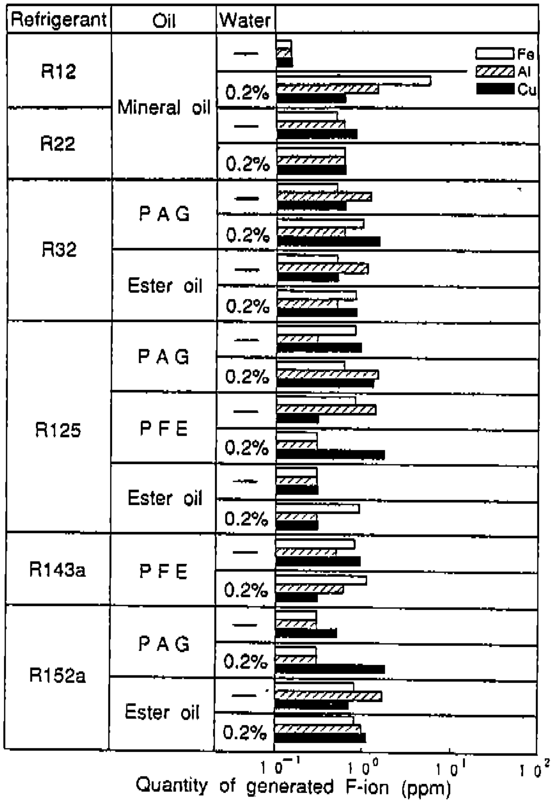

Fig.4 Result of thermal stability test

Table.4 Condition of material compatibility test

Material	Rubbers	Nitrile rubber Silicon rubber Fluorocarbon rubber Acrylic rubber Chloroprene rubber
	Plastics	Epoxide resin Polyester fiber Polyester film Tetron fiber
Temperature	50℃	
Heating period	2 weeks	

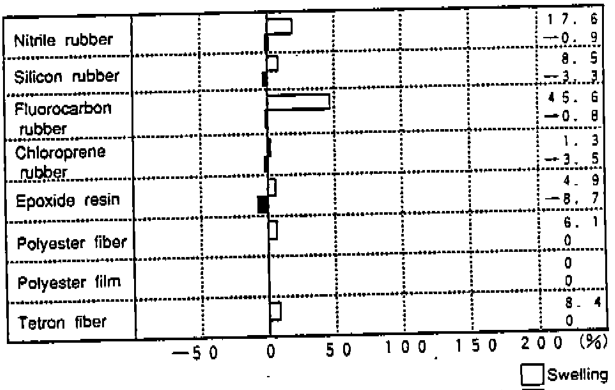

Fig.5 Result of material compatibility test (R32)

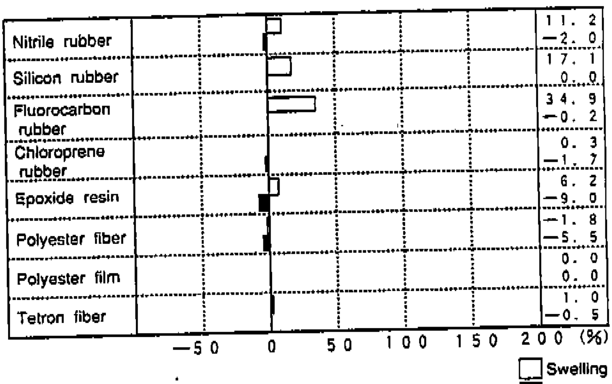

Fig.6 Result of material compatibility test (R125)

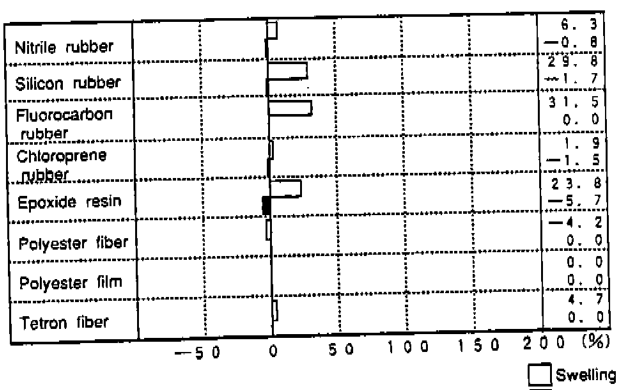

Fig.7 Result of material compatibility test (R143a)

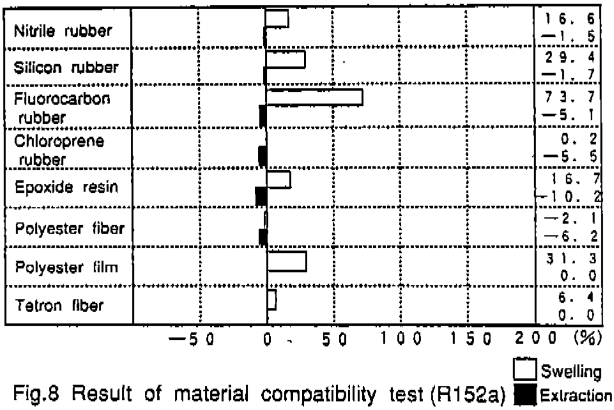

Fig.8 Result of material compatibility test (R152a)

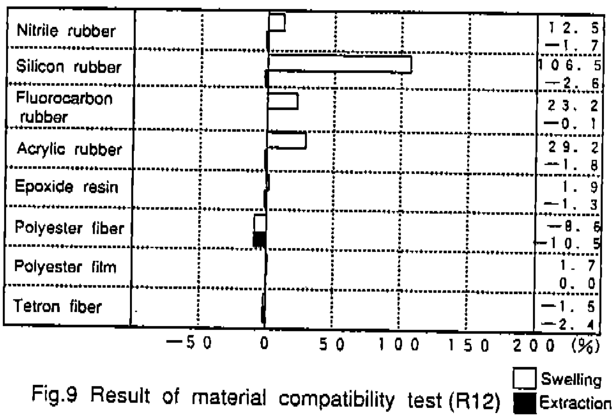

Fig.9 Result of material compatibility test (R12)

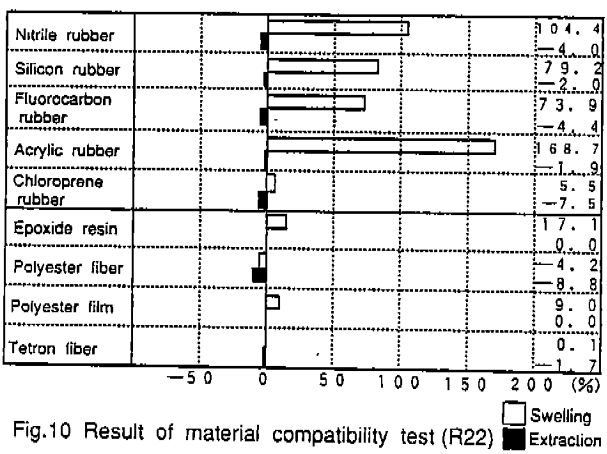

Fig.10 Result of material compatibility test (R22)

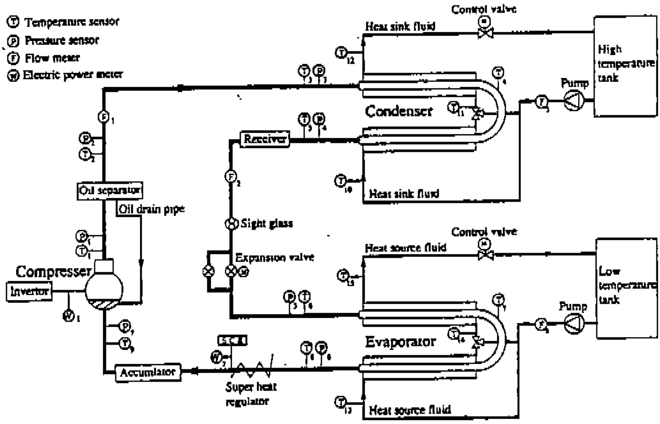

Fig.11 Total system for testing refrigeration performance

Table.5 Performance for HFC refrigerants

		Capacity ratio	COP ratio	Evaporating pressure MPa	Condensing pressure MPa	Discharge temperature difference ℃
R134a	Calculated	1.0	1.0	0.350	1.16	0.0
	Experimental	1.0	1.0			0.0
R152a	Calculated	0.93	1.02	0.315	1.04	7.6
	Experimental	0.96	1.04			7.6
R143a	Calculated	1.67	0.94	0.728	2.06	1.8
	Experimental	1.69	1.01			0.4
R125	Calculated	1.70	0.90	0.784	2.27	−2.2
	Experimental	1.80	0.95			−6.8
R32	Calculated	2.45	0.94	0.949	2.80	28.8
	Experimental	2.48	1.03			30.9

*Operating conditions : Evaporating temp. 5℃, Condensing temp. 45℃, Superheat 9℃, Subcool 10℃

*Capacity : Cooling capacity per suction volume of compressor

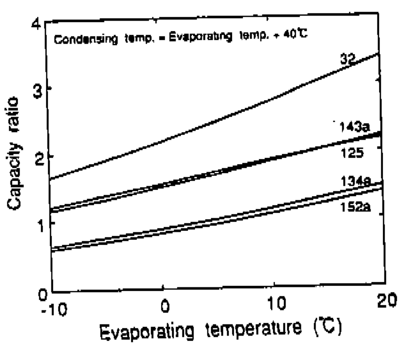

Fig.12 Characteristics of cooling capacity

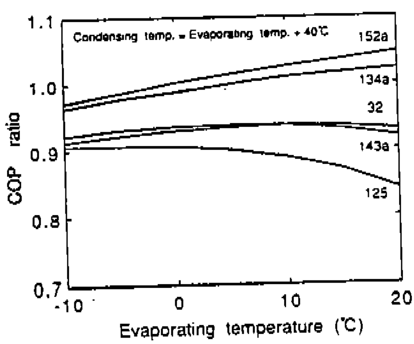

Fig.13 COP Characteristics